TITLE: ECONOMICAL OPTICAL SYSTEM TO PROVIDE REASONABLE ASSURANCE OF COMPLETED VEND OF VENDIBLE ITEMS FROM VENDING MACHINES

INCORPORATION BY REFERENCE

The contents of co-pending, co-owned U. S. Serial No. 10/023,058, filed December 13, 2001, and co-owned U. S. Patent No. 6,540,102, is each incorporated by reference in its entirety.

I. BACKGROUND OF THE INVENTION

A. Field of Invention

The present invention relates to vending machines actuated by user selection after authorization by payment or credit and, in particular, to an apparatus, method, and system of providing reasonable assurance a user-selected vendible item has been vended.

B. Problems in the Art

The vending industry has proliferated and has advanced in technology. It has also expanded the types and variety of vendible items. The very essence of most vending machines is that they are stand-alone machines. They must accurately receive a user selection, confirm adequate money or credit for the selected product, and actuate components configured to automatically dispense the selected product from a secure, stored position in the vending machine.

Much work has gone into advancing the technology surrounding these steps. Highly sophisticated user selection interfaces have been developed. Highly sophisticated and flexible money receivers/changers exist that can handle not only coins, coupons, and tokens but also paper money and, in some cases, credit or debit cards. Much work has also gone into dispensing mechanisms, not only to achieve more reliability and accuracy, but to

also improve use of space inside the vending machine. There have also been substantial advances in security and theft protection regarding vending machines. Again, as previously mentioned, many are stand-alone machines. Some are outside and vulnerable to vandalism or attempts at theft.

Despite the advances in the vending machine field, one area in which development is still needed is verification of an authorized vend. Even if the above-mentioned steps, such as correct receipt of user selection, correct authorization of money or credit, and correct instruction to dispense the selected product, are achieved by a vending machine, there are times when the vendible product does not reach the place the user is allowed access to retrieve it (the "dispensing area" inside the machine).

For example, a selected item can get hung up or jammed between its dispensing mechanism and the user-accessible dispensing area. Sometimes the machine correctly runs the correct dispensing mechanism but there is no product in line to dispense (e.g. because of mis-loading). There can also be malfunctions in the dispensing devices.

Some of these issues are described in more detail in U.S. Serial No. 10/023,058, incorporated by reference herein. These issues are well-known in the art. If a vending machine could verify a vend, customer satisfaction would increase. It would likely decrease instances of vandalism by disgruntled customers. It could also improve inventory/accounting data collection, which can be useful for the owners of the machines or the manufacturers of the vendible items.

Other factors come into play. Any type of vend sensor or vend confirmation system must be practical and cost-effective.

A wide variety of sensors or detection devices are available commercially for detecting the passage or proximity of an item regardless of application. Such sensors or

detection devices are found in applications ranging from production lines to home security. Some utilize optical components. Some are pressure sensitive. Still others utilize some characteristic of or on the item to detect it (e.g., magnetic property, color, shape, size, weight, etc., and radio frequency identification methods (RFID)). There are also energy beam devices such as x-ray or ultrasound. However, some of these methods would not be reliable or accurate enough to be practical for vend verification, especially for a range of shapes, sizes, weights, and types of vendible products. Some of these methods are too complex or expensive to justify in vending machines. Some are not robust enough for vending machine environments. And some are likely ineligible for vending machines (e.g. safety issues with x-rays).

In the past there have been attempts to try to verify a vend by sensing passage towards or arrival at the dispensing area using one of these types of sensing methods. For example, several attempts use a single optical beam across the product path to the dispensing area. If a can or bottle is actually dispensed and passes the beam, interruption of the beam is sensed and is used to confirm the vend.

Single beam optical sensors can work fairly well for machines that are limited to a standard sized, relatively large items, and which have a well-defined product path to the dispensing area. Examples would be twelve or sixteen ounce beverage cans or bottles. The delivery path from the dispensing mechanism to the user accessible dispensing area is usually well-defied, constant, and constrained in size. The single beam can be aligned so that there is reasonable assurance that a passing can or bottle interrupts the single beam. In such cases, a single beam (one emitter/one detector) sensor can be relatively reliable and its cost can many times be justified.

However, detection reliability by a single beam of a variety of shapes and sizes of vendible items that do not have a single, well-defined dispension path to the dispensing area is difficult. For example, candy and snack vending machines handle a variety of containers of different shapes and sizes (including non-food items). Vending machine manufacturers utilize a variety of different types of dispensing mechanisms in such machines. Most times, there are multiple dispensing mechanisms in a single vending machine. Rarely is there a single well-defined path for dispensed items to the user-accessible dispensing area.

Therefore, it is difficult to create a universal vend sensor for such varied containers and machines. And further, the relatively historically low cost of small packages of candy and snacks makes it less economically justifiable to add vend confirmation systems to such vending machines.

Additionally, not only have the variety of shapes and sizes of vendible items proliferated, but their value has increased. For example, vending machines for bottled beverages contain a variety of selections ranging from twenty ounce plastic bottles to 8 ounce glass bottles. Candy and snack type machines handle a wide variety of candies and snacks, but in increasingly varied types, sizes, and shapes of containers. They increasingly handle even non-food items such as fingernail clippers, phone cards, and postage stamps. Many of these types of products are dispensed out of a vertical matrix of rows and columns. There can be a plurality of dispensing mechanisms arranged in a plurality of rows and columns in the machine. The selected product moves out of the front of a dispensing mechanism and is allowed to free fall down to the user-accessible dispensing area. There is no constrained, single delivery path for each vended item along which a vend confirmation system could be installed.

Attempts have been made to create confirmation systems even for these types of vending machines. They tend to be positioned at or near the user-accessible dispensing area. They attempt to discern if a vendible item has been dispensed from any place in the machine.

Some such systems have as their goal to detect any item, no matter what size or shape. This includes attempts at optical solutions to try to cover every part of the dispensing area and any size vendible item. However, these systems require complex arrangements. They tend to be costly or require substantial set-up and maintenance.

For example, one attempt creates a solid plane of light energy across every part of the plane of the dispensing area. It tries to detect any attenuation of the plane of light energy which is indicative of the passage of a vendible item. The components and calibration to accomplish this tend to be expensive and complex. Another attempt closely packs together numerous optical beam emitters along one side of the dispensing area and a corresponding number of closely packed together optical beam detectors along the other side. This would attempt to simulate a solid plane of light energy across the dispensing area to try to ensure that vendible items of even a fraction of an inch in largest diameter would be detected. However, the cost, complexity, and maintenance of such a system could be impractical.

Therefore, there is still a need in the art for a method, system, or apparatus provide reasonable confirmation of a vend, with practical effectiveness and economy. There must be a balance between practical, economical considerations and desire for reasonable confirmation of a vend.

II. SUMMARY OF THE INVENTION

It is therefore a principal object, feature, aspect, or advantage of the present invention to provide an apparatus, system, and method for reasonable confirmation of a vend that improves upon the state of the art.

Further objects, features, aspects, and advantages of the present invention include an apparatus, method, system as above described which:

a. is practical.

b. is economical.

c. provides reasonable vend confirmation for a reasonable variety of types, shapes, and sizes of vendible products.

d. can be installed in a variety of vending machines.

e. is economical in power usage.

f. is durable and long lived.

g. is relatively non-complex.

h. can be installed as original equipment or retrofitted to existing equipment.

These and other objects, features, aspects, and advantages of the present invention will become more apparent with reference to the accompanying specification and claims.

For example, one aspect of the invention includes a method for reasonable confirmation of a vend. A limited number of optical emitters are spaced apart from one another on one side of the dispensing area of a vending machine. A corresponding number of spaced-apart optical detectors are placed on the other side of the dispensing area.

The emitters are turned on and off one at a time in a pre-determined order, in a continuous, repeating sequence separated by corresponding periods where no emitter is operating. The detectors are configured to have a threshold. The threshold is pre-set to

indicate receipt of at least a certain intensity of optical energy of the type generated by the emitters.

The method watches for the passage of vended items by checking if all the detectors trigger each time an emitter is on, which indicates nothing has passed that blocked any detector. If any detector does not trigger during the time any emitter is on, it is assumed a blockage of the emitted optical energy has occurred because of the passage of a vendible item. An output signal is generated by the controller which can be communicated to a master controller of the vending machine, which can interpret the output signal as a confirmation of a successful vend. If all detectors trigger each time an emitter is on, the master controller can assume no vendible item has been vended.

Optionally, the method can generate an output signal if any of the detectors trigger during the times all the emitters are off. This would indicate a possible malfunction of that detector. The output signal in this circumstance can be used to prevent erroneous attempts by the master controller of the vending machine to continue attempts to vend based on a malfunctioning detector.

In this method, there is not comprehensive coverage of the dispensing area at any one time. However, by sequentially turning on emitters for relatively short amounts of time, reasonable coverage of the dispensing area is achieved. This reasonable coverage is achieved with limited power usage, cost, and complexity to provide a practical, economical, reasonable confirmation of vend. It also can allow for continuous checking of operation of the detectors.

In another aspect of the invention, an apparatus includes a first support member or structure upon which are mounted a set of a limited number of emitters spaced apart from one another, and a second support member or structure upon which are mounted a set of a

limited number of detectors spaced apart from another. A microprocessor or controller is operatively connected to the emitters and detectors. It controls an on/off sequence for the emitters, as well as generates an output or error signal if any of the detectors do not trigger during the on-time of any emitter. The error signal is adapted to be in a form that could be sent to another intelligent device, for example, the master controller board of the vending machine, to provide assumed confirmation of vend to the vending machine. The apparatus could be installed as original equipment into a vending machine or retrofitted into existing vending machines by placing the first and second support members on opposite sides of a dispensing area. The microprocessor can also generate an error signal if any of the detectors trigger during the off-time of the emitters, because it indicates a malfunction of a detector.

III. BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a simplified perspective view of a candy and snack type vending machine **1** showing multiple dispensing mechanisms and a user-accessible dispensing area **10** below those mechanisms, and illustrating diagrammatically placement of emitter and detector support members, here printed circuit boards **20** and **26**, according to an exemplary embodiment of the present invention.

Figure 2A is an enlarged cross-sectional view taken generally along line **2-2** of **Figure 1**, looking from above at emitter board **20** and detector board **26** relative to the vending machine dispensing area **10**. **Figure 2A** also illustrates diagrammatically the beam pattern of one emitter relative the detectors.

Figure 2B is similar to **Figure 2A** but shows diagrammatically operation of a second emitter.

Figure 3A is a detailed plan view of printed circuit emitter board **20** of **Figure 1**.

Figure 3B is a schematic depiction of structural features, such as mounting holes and registration marks used during surface mount technology (SMT) manufacturing process for the emitter board of **Figure 3A**.

Figure 3C is an electrical circuit diagram for the emitters of the emitter board of **Figure 3A**.

Figure 4A is a detailed plan view of a printed circuit detector board **26** of **Figure 1**.

Figure 4B is a schematic depiction of structural features, such as mounting holes and registration marks of the detector board of **Figure 4A.**

Figure 4C is an electrical circuit diagram for the microcontroller and certain affiliated components of the detector board of **Figure 4A**.

Figure 4D is an electrical circuit diagram for a power supply circuit for the detector board of **Figure 4A**.

Figure 4E are electrical circuit diagrams for infrared optical detectors on the detector board of **Figures 4A**.

Figure 4F are electrical circuit diagrams showing connections of the microprocessor to the emitters of **Figure 3C** and an output stage of detector board **26** of **Figure 4A** for communicating an output signal to a master controller board in a vending machine.

Figure 5 is a flow chart of programming for operation of emitter and detector boards **20** and **26** of **Figures 1-4** according to an exemplary embodiment of the present invention.

IV. DETAILED DESCRIPTION OF AN EXEMPLARY EMBODIMENT OF THE INVENTION

A. Overview

For a more complete understanding of the invention, one exemplary form it can take will now be described in detail. Frequent reference will be made to the drawings. Reference numerals and letters will be used to indicate certain parts and locations in the drawings. The same reference numerals and letters will be used to indicate the same parts and locations throughout the drawings, unless otherwise indicated.

B. Environment of Exemplary Embodiment

The exemplary embodiment will be described in the context of installation in a conventional snack vending machine which vends a variety of products such as candy, snacks, phone cards, personal care products, and other vendible items. A plurality of what will be called trays, at separated horizontal levels inside the machine, each have a plurality of individually controllable dispensing mechanisms. This type of configuration is well known in the art. An example of such a machine can be found at U.S. Patent 6,540,102, incorporated by reference herein.

As diagrammatically illustrated in **Figure 1**, each horizontal tray **A, B, C**, or **D** of machine **1**, has individual dispensing mechanisms. Therefore, product selection can be made by selecting from the vertical matrix of **A1** to **D4** (rows **A-D** and columns **1-4**), by selecting a tray (row **A, B, C**, or **D**), and a dispensing mechanism in that tray (e.g., selection **B2** would operate the dispensing mechanism at the second column from the left in the second tray from the top.)

A standard or conventional product selection module **7** and money changer/credit module **8** are associated with the machine **1** and connected to a master vending machine

controller board **34** (see **Figure 2A**). Controller board **34** would issue signals to the dispensing mechanism in the appropriate row and column of the appropriate tray in machine **1** upon selection and confirmation of sufficient money or credit.

Figure 1 illustrates a user-accessible dispensing area **10** underneath a free-fall product drop zone (between the glass front of the vending machine and the dispensing ends of the columns inside the vending machine).

Figure 2A diagrammatically illustrates a generally cross-sectional horizontal plane at or near the dispensing area of the vending machine. In the diagram, the perimeter of vending machine **1** generally includes floor **6**, front **2**, back **3**, left side **4**, and right side **5**. The perimeter of dispensing area **10** (which is inside vending machine **1**) is illustrated, including floor **16** defining the bottom of a drop or dispensing area for machine **1**. Back, left, and right vertical walls **13**, **14**, and **15** enclose three sides of the dispensing area. As indicated at **Figure 1**, the front of the dispensing area is not enclosed (it may have a moveable access door – not shown), as customers must be able to reach into the dispensing area. The front edge of the dispensing area is indicated by reference number **12** in **Figure 2A**. It is to be understood, however, that dispensing area **10** does not have to be enclosed by walls, or even have a floor. It is intended to refer to a designated space where dispensed products from the vending machine would be directed so that a customer can access them.

The above vending machines features are well-known in the art and will not be described further.

The exemplary embodiment of the invention will also be described in the context of a vending machine having a master controller board **34** which has programming adapted to work in conjunction with the vend sensing system of the exemplary embodiment. In particular, the master controller board can include programming which tries to ensure a

vend takes place in response to an authorized vend selection. This program or regimen is described in co-pending, incorporated by reference U. S. Serial No. 10/023,058. The regimen can rely upon a vend sensor for part of its methodology. For example, the regimen can rely on a signal from a vend sensor to make an assumption about whether or not a product was dispensed. If the vend sensor does not send a signal indicative of confirmation of a successful vend, the regimen can instruct operation of another full or partial vend cycle to try to provide the customer with at least one selected product. However, it is to be understood that the regimen of Serial No. 10/023, 058 is not required for use with the present invention, and conversely, the vend sensor apparatus and method of the present invention are not required to be used with the regimen described in Serial No. 10/023,058. The regimen of Serial No. 10/023,058 will be used for illustration only in the example of the invention below.

C. Apparatus

A vend sensor apparatus according to an exemplary embodiment of the invention includes two separate support members or structures, here circuit boards **20** and **26** (see **Figure 1**). They are configured to be installable on opposite sides of dispensing area **10** (by screws, bolts, or other connecting or mounting structure). An electrical cable **28** allows electrical communication between boards **20** and **26**. A connection **32** allows electrical communication with a master controller **34** of vending machine **1**.

Figures 2A and **2B** are not to scale but are intended to diagrammatically illustrate more detail of boards **20** and **26**, as well as their operation as a vend sensor, which will be discussed in more detail later. The first board, sometimes called emitter board **20**, includes five spaced apart infrared (IR) light emitting diodes (LEDs) **D2, D3, D4, D5**, and **D6** (sometimes collectively referred to as emitters **D**). The second board, called detector board

26, has five spaced apart IR detectors **U2**, **U3**, **U4**, **U5**, and **U8** (sometimes collectively referred to as detectors **U**).

Emitter board **20** and detector board **26** can be implemented as illustrated in **Figures 3A-B**, and **4A-F** respectively. The size and configuration of boards **20** and **26** has been selected to fit many, if not most, snack-type vending machines. It can be created to mount into new machines or be retrofitted into existing machines. It includes an electrical interface that can communicate with master controller board **34** and/or other existing equipment in vending machine **1**.

Boards **20** and **26**, to operate correctly, must be spaced a minimum distance of 9.824 inches (250 millimeters) to a maximum distance of 34.652 inches (880 millimeters).

Surface mount components are utilized on boards **20** and **26**.

1. Emitter Board

Referring to **Figure 3A**, emitter board **20** is approximately one by six inches in perimeter dimensions. The five emitters **D** of emitter board **20** are generally equally spaced approximately one inch apart. Emitters **D** are electrically connected to header **36** (also indicated by J2).

The components of emitter board **20** can be predominantly surface mount technology, such as is well known. **Figure 3B** schematically illustrates structures on the PCB emitter board such as mounting holes and fiducials (registration marks used during the SMT manufacturing process) that are essentially a part of the board and not the circuit. Items labeled X1-X4 represent plated mounting holes. Items X5 and X6 represent unplated mounting holes by J2 to hold the cable.

Figure 3C illustrates the electrical circuitry of emitter board **20**. Seven pin header **36** (available from FCI under Part No. **55101**-XXX**7**, **7** contact, **0**.**1** inches RA header)

communicates to header **52** (Figure 4A) on detector board **26** via cable **28 (Figure 2A)**. This connects processor **30** to emitters **D**.

Details regarding the parts indicated in **Figures 3A-3C** are listed in **Appendix 1** to this description.

It is to be understood that although two sets of emitters are shown in parallel (set **D2, D3**, **D4**, **D5**, **D6** versus set **D1**, **D7**, **D8**, **D9**, **D10**) in **Figure 3C,** only one set is needed and used. **Figure 3C** is intended to illustrate two possible alternative options for the five emitters **D**. One option is Kingbright AP3216P3C infrared diodes (package 1206, approximately 3.2 mm by 1.6 mm SMT (Surface Mount Technology) LED, 1.1 mm thickness). Another option is Lumex OED-EL1206C140 infrared diodes (through-hole (TH) package). It is possible that circuitry could be built into board **20** to allow either set. However, only one set or the other would be installed or operated on board **20.**

IR radiation from each emitter is generally directional but has some beam spread. The emitters are mounted so that they aimed generally orthogonally from the plane of board **20**. Emitter beams will be modulated using an approximately 40 kilohertz square wave.

2. Detector Board

Detector board **26** is approximately one by six inches in perimeter dimensions (see **Figure 4A**. Detectors **U2, U3**, **U4**, **U5**, and **U8** (Lumex product OED-MRM791-2F, package TH, approximately 6.8 mm by 7.76 mm by 5.5 mm in dimensions) are generally equally spaced apart about one inch (generally matching the spacing of emitters **D**. Detectors **U** are also positioned generally orthogonally to board **26**.

Figure 4B is a diagram for board **26** showing additional information about board **26.** Similar to **Figure 3B**, **Figure 4B** illustrates structures such as mounting holes in

fiducials on detector board **26**. Items X1-X4 are mounting holes for board **26** to the vending machine. Items X5-X9 are registration marks for SMT manufacturing processes. Items X9-X12 are tie-down holes for cables.

Detector board **26** includes microprocessor **30** (Texas Instruments MSP430F1121PW CPU, SMT). **Figures 4C-F** are electrical schematics of detector board **26**. They illustrate the electrical interconnections between components. Specific details for parts of detector board **26** are listed in **Appendix 2.** Interconnect cable details are shown in **Appendix 3.**

Microprocessor **30** controls a number of functions. One is on/off operation of emitters **D** via cable **28**. Another is monitoring the output of detectors **U**. Another is generation of an output signal to what will be called an output stage of the detector board circuitry (see **Figure 4F**), which can connected via a connection **32** from detector board **26** to a master controller board **34** for vending machine **1**. The output signal from microprocessor **30** can be a signal indicative of the detection of a vended item by the vend sensor, as will be discussed later. An appropriate interface (e.g. appropriate connectors, pin-outs, and power requirements) is used to communicate with master controller board **34**.

Microprocessor **30** includes FlashRom for program memory and RAM for data memory. **Figure 5** is a flow chart of the firmware code. Microprocessor **30** is programmable and debuggable through two by seven pin header **70** (also indicated at reference J2). C programming language is used to develop the firmware for microprocessor **30**. Some assembly language may be needed in certain speed critical areas of the code.

As can be seen by referring to **Figures 3C**, **4A**, and **4F**, cabling **28** uses plug-in connections **36** and **52** to communicate the emitters on board **24** to board **26**. Specifically,

emitters **D** are connected to ports **85**, **86**, **87**, **88**, and **89** of microprocessor **30** (See **Figures 4C** and **4F**). As shown in **Figure 4C**, crystal **54** provides the modulated frequency for emitters **D**. It can also provide a clock source for other functions.

The circuitry of board 26 uses existing supply power available at vending machine **1** (usually 15-30 volts DC). A specific power supply circuit for board **20** and **26** is shown at **Figure 4D**. The power supply circuit of **Figure 4D** plugs in at five pin receiver **50** on board **26** (**Figure 4A**) via a matched cable/header. Low drop-out, positive voltage regulators **U5** and **U7** provide power levels (5.0 V and 3.3 V) to microprocessor **30**, and current limiting, and thermal shut down. Transient overvoltages are absorbed by transient/surge absorber **56** (component Z1). The reset circuit associated with the three pin microprocessor reset circuit of **Figure 4C** (including component **U9**, ref. no. **68**) is a supervisory circuit that can be used to monitor the supply voltages for in microprocessor **30**. It provides a reset to the microprocessor during power-up, power-down and brown-out conditions. Although shown, Jumper JP2 in **Figure 4D** is not populated (is open) in this embodiment, as it is not needed.

The five detectors **U** are illustrated schematically at **Figure 4E**. They are connected to microprocessor **30** at microprocessor inputs **80-84**, as depicted in the schematic of **Figure 4C**. Detectors **U** are configured to detect certain levels of light energy. The state of each detector **U** varies depending upon which side of a threshold it is detecting. Microprocessor **30** monitors which state each detector **U** is in.

Emitters **D** are powered by instruction from microprocessor **30** by controlling on/off states of transistor Q5 (**Figure 4F**) via microprocessor output **93** (output P1.2, see **Figure 4F** and **4C**). Both electrical power and emitter on/off instructions are communicated through cable **28** between header **52** on detector board **26** to header **36** on

emitter board **20**. Emitter angle is approximately 30 degrees. Pulse frequency is 38 kilohertz. Pulsation is 250 microseconds or less. The emitters are fired in a pre-determined order, namely **D2, D5, D3, D4, D6** for emitters **D** in **Figure 3A**. Note that emitters **D2** and **D3** are nearest the outside edges of board **20**, and thus usually nearest any walls other structures at the periphery of dispensing area **10**. Each beam from emitters **D** is modulated to at or around 38 kilohertz (KHz) so that any ambient light or reflections do not interfere with the sensitivity or operation of the device. In other words, the light detected by detectors **D1-D5** must be modulated at approximately 38 KHz in order to be detected.

Detectors **U** are essentially "matched" to emitters **D** in the sense they are configured to respond only to light energy of the wavelength of the light emitted by an emitter **D**. Detectors **U** amplify and filter any detected signal generated by the LED emitters **D** on the emitter bar or board **20**. The amplifier contains an automatic gain control (AGC) circuit that adjusts the gain of a detector amplifier to maintain a constant signal level at the output of the amplifier. The filter contains circuitry to reject all signals except those modulated (turned on and off) at an approximately 38 kHz rate (38 kHz-40 kHz). The presence of the filter requires the LED signal to also be modulated in an on and off fashion at the 38 kHz rate. Besides the signal filtering, the detector also contains optical filtering to reject all light except for a narrow spectrum of light centered at 880 nanometers. The two types of filters allow the detectors to not be affected by stray extraneous light.

Figure 4F also shows the output stage of the vend detect circuitry. Connection **90**, output P2.5 from microprocessor **30**, is the input to an open collector transistor stage (1000 ohm, 5V pull up) including transistors **64**, **60**, and **62**.

If no output signal is sent by microprocessor **30** to output **90**, indicating that nothing is blocking any detector **U**, transistor **64** is non-conducting. Output **91** is therefore

in its "high" state. Transistor **60** would therefore also be non-conducting, and node **95** would be "high". Because node **95** is "high", transistor **62** would be conducting, and output **92** would be "low".

On the other hand, if microprocessor **30** does send an output signal to output **90,** indicating a detector **U** has been blocked, transistor **64** becomes conducting, and output **91** is pulled "low". Transistor **60** would become conducting. Node **95** would be pulled "low" and close the gate of transistor **62**, causing transistor **62** to cease being conducting. Output **92** would therefore go "high".

Therefore, outputs **91** and **92** would always be in opposite or inverted states. Either output **91** and **92** can be used by master control board **34** as a signal whether a vend has been detected. As can be appreciated, only one output **91** or **92** would be needed to inform master controller **34**. However, this arrangement allows the circuitry to have available two different outputs. Different master controller boards can require different communications. Therefore, two outputs allows the vend sense circuit to be adaptable to a wider variety of master controller boards and vending machines. For example, a certain master controller board may want to see a output pulled low to indicate a vend. Another master controller board may want to see an output pulled high to indicate a vend. Thus, outputs **91** and **92** are essentially inverted from one another to provide either option.

LED **58** is mountable on detector board **26** at the location labeled D2 in **Figure 4A** and, as shown in **Figure 4F**, functions to indicate status of operation of the circuit. LED **58** will light so long as no output signal is generated at **90.** As will be explained further, this occurs in two conditions, (a) when all detectors **U** are indicated to be working properly and (b) when all detectors **U** indicate they "see" the beam from each emitter **D**. LED **58** will have sufficient power to operate whenever there is no output signal at **90** (node **95** will

be "high"). This feature not only provides a visual indicator of what state the vend sense circuit is in, but can also be used to correctly install emitter and detector boards **20** and **26.** The circuit can be powered up and boards **20** and **26** tentatively positioned in vending machine **1.** If emitters **D** and detectors **U** are properly aligned, i.e. each detector **U** "sees" the beam from each emitter **D** when they are on, LED **58** will light up. If there is misalignment, LED **58** will not light. The worker installing the boards can simply adjust the position of the boards **20** and **26** until LED **58** lights.

LED **58** will remain on until a detector **U** indicates attenuation of received IR energy or malfunctions. When this occurs, LED **58** will remain off until microprocessor **30** communicates the object has cleared or the malfunction has resolved.

The vend sensor circuitry is designed to operate off of 24 volts DC power at less than 200 milliamps. It interfaces to master controller board **34** by pulling low the output of the open-collector transistor buffer. The output signal will be activated for a minimum of 150 milliseconds and a maximum of 300 milliseconds after detection (e.g. set in software). The output signal will be pulled active whenever a light beam from an emitter **D** is blocked. The signal will reset 150 milliseconds after the blockage is removed.

As can be appreciated, there are a variety of ways for microprocessor **30** to send an output signal which can be used by a master controller board. For example, instead of controlling operation of transistor(s), microprocessor **30** could activate one or more relays, which could act as a switching device to provide a signal for use by the master control board. Other methods of creating a signal that can be used by vending machine **1** are possible. However, use of solid state transistors might make it possible to dispense with circuitry included primarily to isolate the detector circuitry from the master controller circuitry.

3. Operation

Operation of the vend sensor system of **Figures 1-4F** is according to the algorithm of **Figure 5** is as follows. Microprocessor **30** is programmed accordingly.

a. Set up.

The system is installed into the vending machine. Boards **20** and **26** should be positioned within the recommended range of distances from one another. They should also be aligned to make sure that each detector **U** triggers or turns on when each emitter **D** is turned on when nothing is between the two boards **20** and **26**. The procedure previously described regarding LED **58** can be used for this purpose.

b. Initialization.

The variable N, the emitter count, is set to the value 0 (**Figure 5**, step **200**). During operation, variable N sequences from 1 to 5 the sequence corresponding to the five emitters **D2**, **D3**, **D4**, **D5**, and **D6**. Microprocessor **30** also instructs initialization of the emitter modulator (step **202**) to modulate operation of each emitter when turned on. In this example, emitters **D** are modulated at 38 kHz. Detectors **U** are configured to recognize and respond only to IR energy at around 38 kHz. This helps accuracy of the system. It tends to ignore other light, including ambient light, that otherwise might cause falsing.

Various timers or clocks are initialized. These timing devices can be based on external crystal **54** or otherwise. The needed timing values will be explained below.

Part of the timing of the circuit involves what will be called a relay count. This is a software value that is initialized to 0 (zero) (can be a number assigned to a register). The relay count controls both whether, as well as the length of time, the microprocessor generates its output signal. As can be seen at steps **226**, **228**, and **236**, so long as the relay

count is 0, no output signal will be generated by microprocessor **30** (steps **226** and **236** – the output line **90** is kept off or is turned off). On the other hand, so long as the relay count is above 0, the output line **90** is turned on or active by microprocessor **30**.

The relay count remains 0 unless either of two conditions are sensed by the circuit, namely (a) a detector **U** malfunction while all emitters **D** are off or (b) a detector **U** is blocked while an emitter **D** is on. If either condition (a) or (b) is sensed, the value of the relay count is essentially set to correlate to the 150 ms period of either step **214** or **234**. One way to set the relay count is as follows.

The cycle time of the circuit through its main loop is known (here about 500 μsec – 250 μsec of all emitters off, following by 250 μsec of one emitter on). Thus, about 300 main loop cycles would take up about 150 ms (150 ms divided by 500 μsec). Thus, the relay count can be set to a value of 300 for steps **214** and **234**, and the relay count decrement amount in step **228** can be set to 1. Thus, it would take 300 main loop cycles or approximately 150 ms to decrement a full relay count to zero. If either a detector malfunction is indicated during the detector check of step **210**, or a product vend is detected during an emitter on-time of step **234**, microprocessor **30** loads the relay count value into a register. The precise value of the relay count will, of course, be dependent on the clock source chosen.

As indicated at steps **226, 228**, and **236**, so long as the relay count stays greater than 0 (step **226**), the program decrements the relay count (step **234**) and returns to the beginning of the main loop (step **206**), but leaves the output signal on or in the "blocked" state. Thus, so long as a detector is malfunctioning or indicates blockage, the circuit output will be turned on. Essentially, in either case, the circuit reports an "error" condition. The master controller board will interpret it as an item has vended, and, if the regimen of Serial

No. 10/023,058 is used by master control board **34**, will not try to keep vending until released from that state.

The algorithm of **Figure 5** turns the output line off only if either of the two conditions stops, and then only after it runs through the main loop enough times to decrement the initial relay count value to 0 (zero), i.e., for approximately 150 ms.

But, as can be seen from **Figure 5**, the relay count is basically retriggerable. Each time through the main loop, if either of the two conditions are met in steps **210** or **224**, the relay count is reset to its maximum value. It is only after both of the conditions have cleared (no detector malfunction is indicated and no detector blockage is sensed), that the algorithm will decrement down to zero.

However, if desired, the software running the algorithm can have a maximum time limit for the output signal. For example, for any vend instruction from master controller board **34**, a maximum output signal "on" time (e.g. 300 ms) could be set. The master control board would interpret any output signal from the microprocessor **30** that lasts at least 150 ms as being an indication of an "error" condition (detector malfunction or detector blockage). The software would allow one retriggering of the 150 ms relay count as a redundancy check, and then reset the relay count to 0, ready to sense the next vend. Of course, there does not have to a maximum or it could be set to a different value, as might be desired.

Initialization also includes setting the emitter modulator (step **202**). As discussed earlier, the emitters are modulated to approximately 38-40 kHz. Other modulations and methods to do so can be used.

c. Begin Main loop.

What is called the main loop begins (step **204**) with microprocessor **30** turning off all emitters **D** on board **20** (Step **206**) for a set period of time, here 250 microseconds (μs) (step **208**).

(1) Detector Check.

At the beginning of each iteration of the main loop, the operation of detectors **U** is checked. Through scanning inputs **80-84**, microprocessor **30** checks if all detectors **U** are off (step **210**), i.e., not detecting any relevant IR energy. In other words, it checks to make sure no detector is indicating receipt of IR light energy at the modulated frequency above its triggering threshold, which would indicate a malfunction of that detector because all emitters are off at that time. If any detector **U** is on at this point, microprocessor **30** generates an output signal at the output stage of detector board **26** (step **212**). This is essentially an error signal because the circuitry is not monitoring whether a vended item has dropped, it is testing operation of the detectors.

For example, as indicated at **Figure 5**, if any detector **U** does detect relevant IR energy during the all-emitters-off time period, microprocessor generates the output signal at output **90** which pulls the output **91** low as an indication that something is wrong with the hardware. This function is realized as a failsafe or cautionary procedure. The system assumes there is a problem if a detector **U** indicates receipt of IR during the time all emitters **D** are off. This checks the "health" of detector elements **U**, primarily testing if a detector has failed in an "on" state. Also, it can catch if someone is "spoofing" the vending machine with a remote control IR source. As will become clearer below, without this function, a malfunctioning detector **U** might indicate it is receiving IR energy from an emitter, when in fact it is not. Essentially, the vend sensor would miss any vended item

and would fail to inform master controller board **34** if a product dispenses to the dispensing area, when in fact it has actually been delivered. This is problematic because under the vending regimen of Serial No. 10/023,058, master controller board **34** would mistakenly try to dispense. This may result in dispension of a second item, when the customer has already received the item.

It is noted that if either an emitter or detector fails in the "off" state, this will be assumed to be a permanent light being blocked during normal operation which could also be interpreted as grid misalignment. This would cause the output on line **32** to controller board **34** to drop low which would be the desired state for this circumstance. Therefore, no additional processing is needed to monitor that condition.

If the detector check (steps **208**, **210**) results in a "blocked" or "error" output signal (step **121**), microprocessor **30** sets a timer to 150 milliseconds(ms) (step **214**) (or, equivalently, sets the relay count), and the program moves to the next step. The 150 ms is the minimum amount of time the output line is activated. In other words, if a detector malfunction occurs only once during the main loop, the output line will be set to "blocked" for 150 ms, and then set to "unblocked". However, as discussed above, the output line will be set to "blocked" as long as the condition of step **212** is met during each loop of the algorithm, and there can be a maximum time, if desired, after which the output is reset to "unblocked".

(2) Emitter operation.

Regardless of whether all detectors are indicated off and functioning properly in step **210**, or whether a malfunction is indicated and the 150 ms timer is set in step **214**, microprocessor **30**, through its appropriate output **85, 86, 87, 88, or 89**, activates a first

emitter (in this example emitter **D2** of **Figure 3A**) for the time period in **Table 1** (step **216**).

Table 1

Emitter (as shown in **Figure 3A**)	Duration
D2	250 μs maximum
D5	250 μs
D3	250 μs maximum
D4	250 μs
D6	250 μs

The control of the order of illumination of the individual emitters ensures that the total amount of light striking each detector is essentially constant over an illumination cycle. An illumination cycle consists of the steps of enabling each emitter in turn with a properly modulated signal. The modulation of the beam allows the received beam to be filtered to reduce sensitivity of the detector to ambient light. The staggering of the "firing order" of the emitters ensures that each detector receives, to some degree, uniform illumination over the course of an illumination cycle.

Variable N is incremented by 1 (step **218**) and microprocessor **30** checks if N=5 (step **220**). During the first pass through the loop, N is not equal to 5 (i.e., N=1). Therefore, the first emitter is instructed to remain on for 250 microseconds minimum (see **Table 1**) (step **222**). This time, microprocessor **30**, via inputs **80-84**, checks if all detectors **U** are on, that is, it checks whether all of the five detectors are receiving at least their threshold level of IR energy from the emitter that is on. Four different conditions can exist at this point in the main loop.

First, if all detectors **U** passed the detector test of steps **206/208/210** and all the detectors **U** are on during steps **222/224**, indicating each detector "sees" the emitter that is on, microprocessor **30** checks the relay count (step **226**). Under this condition, the relay

count is 0 (zero). It has not changed from its initialized value. The output line will not be activated (step **236**). During this first pass through the main loop of **Figure 5**, the vend sensor indicates that (a) all detectors appear to functioning correctly, and (b) nothing has blocked any detector. Therefore, the vend sensor does not pass any indication that a vend has occurred to the master controller. Under the regimen of serial number 10/023,058, if a vend has been authorized, the master controller will wait a while to see if the vend sensor indicates a vend has occurred during the next iteration of the main loop.

Second, if all detectors **U** passed the detector test of steps **206/208/210** but all the detectors **U** are not on during steps **222/224**, microprocessor **30** turns the output line on (step **232**) and sets the timer (the relay count) to the equivalent of the 150 ms period (step **234**). This creates the indication that at least one detector does not "see" the emitter that is on and makes the assumption it was the result of a vended item blocking that (those) detector(s). Microprocessor **30** then checks the relay count (step **226**) and will find it is greater than 0 (zero). During this first pass through the main loop of **Figure 5**, and under this second condition, the vend sensor indicates that (a) all detectors appear to functioning correctly, and (b) the selected item has been vended. And, by turning the output line on or active, the vend sensor passes the indication that a vend has occurred to the master controller. Under the regimen of serial number 10/023,058, the master controller will discontinue any further attempt to vend an item and reset for the next vend instruction. Before, returning to the main loop, the relay count is decremented by the pre-set amount (step **228**).

Third, if any detector **U** did not pass the detector test of steps **206/208/210**, microprocessor **30** still checks whether or not all the detectors **U** are on during steps **222/224**. Assuming, under this third condition, that all detectors are indicated to be on

during the period of time emitter **D2** is on, microprocessor checks the relay count (step **226**). However, under this third condition, the relay count has been set to its 150 ms equivalent at step **212** because of the malfunction of a detector. Therefore, even though all detectors appear to "see" emitter **D2** when it is on at step **224**, the output line has been turned on for **150** ms at step **212** and the relay count is greater than zero. As a result, the output line will remain activated (it will not be turned off) but the relay count will be decremented (step **228**). The master controller does not differentiate between a detector malfunction at steps **210/212** and an indicated blockage at steps **224/232**. The regimen of serial number 10/023,058 simply sees the output line high and discontinues any attempt to continue to vend from that dispensing mechanism, for the reasons discussed previously.

Fourth, if any detector **U** does not pass the detector test of steps **206/208/210**, microprocessor **30** will immediately turn the output line on and set the timer to the 150 ms value (by setting the relay count). Microprocessor **30** still checks whether or not all the detectors **U** are on during steps **222/224**. Assuming, under this fourth condition, that one or more detectors are indicated to be off during the period of time emitter **D2** is on, microprocessor leaves the output line on (step **232**) and resets (or retriggers) the timer to its 150 ms equivalent. Microprocessor then checks the relay count (step **226**). Under this fourth condition, the relay count was been set to its 150 ms at preceding step **212** because of the malfunction of a detector, and again at step **234** because of an indicated blockage of one or more detectors. Therefore, the relay count is greater than zero. As a result, the output line is activated but the relay count will be decremented (step **228**). Again, the master controller does not differentiate between a detector malfunction at steps **210/212** and an indicated blockage at steps **224/232**. The regimen of serial number 10/023,058

simply sees the output line active and discontinues any attempt to continue to vend from that dispensing mechanism, for the reasons discussed previously.

At the end of the first iteration of the main loop at either step **228** or **236**, the algorithm returns to the start of main loop (step **204**). On the second iteration of the main loop, a detector check is again made (as described above and shown at steps **206/208/210**). Then, a second emitter (in this example emitter **D5**, see **Table 1**) is turned on, N is incremented to N=2 (steps **216/218/220/222**), and detectors are checked to see if they "see" the light from emitter **D5** (step **224**).

As described above, the algorithm again can be in one of the above-described four conditions, except for one major difference. If the output line had been turned on at either or both steps **212** or **232** during the first iteration of the main loop, the output line will already be turned on and the relay count will be greater than zero. Therefore, even if no malfunction or blockages are indicated at steps **210** or **224** during the second main loop iteration, the relay count (step **226**) will be greater than zero and the relay count will be decremented (step **228**), but the output line will stay on and the algorithm moves to the next iteration of the main loop. If no malfunction or blockages are indicated at steps **210** or **224** for subsequent iterations of the main loop, the output line will remain on until the relay count is decremented to zero, at which time (step **226**) the output line will be turned off (step **236**). In other words, this embodiment of the algorithm has intentionally designed that once the output line is turned on, it should remain on a minimum of the amount of time it takes main loop the cycle for 150 ms. This provides the master controller with a pulse at least 150 ms long from the vend sensor.

But, on the other hand, if during the second main loop iteration, either a detector malfunction or a detector blockage is sensed, the output line is set to or maintained high,

and the timer/relay count is reset to its maximum. Thus, every instance of detector malfunction or detector blockage resets the output signal high for at least the minimum 150 ms time.

But, as mentioned, the algorithm could turn the output line off after a maximum limit of on time. Here that maximum is selected to be 300 ms, because it would tend to indicate a perpetuating error situation if that condition occurs that long a time.

The main loop is then repeated in this fashion for the third, fourth and fifth emitters in the order of **Table 1**; that is, until N=5 (step **220**), which means all five emitters have been sequentially activated with the intervening off times of steps **206** and **208**). The algorithm would function similarly during operation of the third, forth, and fifth emitters, and subsequent main loop iterations, and therefore, they will not be described further except as follows.

When N=5, variable N is reset to 0 (step **230**), and the main loop starts over with all emitters off, then the first emitter on, then all emitters off, then the second emitter on, and so forth. The predetermined sequence of firing of emitters **D** of **Table 1** is repeated over and over so long as the circuit is powered.

Therefore, the program of **Figure 5** activates each source emitter **D** individually. Not all emitters **D** are on simultaneously. The method checks that each emitter **D** is "seen" by all detectors **U** on the other side of the vend area **10**. The sequence of firing of emitters **D** is shown in **Table 1**. Any sequence can be used but, in this embodiment, the sequence and on-times are selected because of the following. The maximum "on time" for any emitter, as indicated in **Table 1**, is 250 microseconds (0.000250 seconds). During this period, the system checks to see that all detectors **U** are detecting infrared from the emitter on at that time. After an emitter is turned off, the system waits another 250 microseconds.

After this delay, the next emitter **D** in sequence is turned on and the system checks to see if all detectors **U** "see" that beam. But, as noted in **Table 1**, not all emitted beams are treated equally. In order to counter-act glancing reflections off of the inside of the vending machine, which can prevent the emitters and detectors from being properly aligned, the five emitters **D** are pulsed as indicated in **Table 1**. In the case of beams from the outside two emitters **D2** and **D3** of **Figure 3A**, the beam is shut off "early" if the detector board **26** indicates all detectors **U** are detecting the beam. This is to cut down on shallow angle reflectance on the inside of structure defining the dispensing area in the vending machine. When an emitter **D** is shut down "early", it still will wait 250 microseconds before going on to the next step in the algorithm of **Figure 5**.

An example of compensation that could be used with the exemplary embodiment is further described as follows. The software could be programmed to contain compensation for the reflected light received by the two outer detectors. During normal algorithm operation, stray light from the emitters often reflects from surfaces inside the machine onto the detectors. The two outer detectors, because of their placement, receive more reflected light than the inner detectors. The stray light pickup by the outer detectors affects them by decreasing their overall sensitivity to the light generated by the emitters. This is due to the presence of the AGC circuit in each detector that reduces the sensitivity of the detector in proportion to the amount of light received. The sensitivity decrease causes a problem with detecting the lower light intensity at the outermost detector at one end of the detector board when the outermost emitter at the opposite end of the emitter board is energized. The problem can manifest itself as a false beam-blockage detection.

A solution for this problem is to compensate for the effect of the reflected beams by shortening the total time the outside emitters are on to the minimum needed to generate the

correct unblocked condition in all detectors. This is implemented by reducing the amount of time the outer two emitters are on (see **Table 1**) to minimum amount needed for normal operation of the light curtain. An illumination cycle is divided into five equal time periods. Each time period is associated with the illumination of one of the emitters. An emitter occupying an inner position (any of the three positions between outermost emitters) of the emitter board or module 20 is enabled for a fixed time occupying most of its time period during an illumination cycle. An emitter occupying one of the outer positions is enabled only until all detectors detected the signal. Then it is disabled for the remainder of that emitter's time period. The reduced amount of time the outer emitters are enabled reduces the total amount of light reaching the outer detectors. This prevents the occurrence of the reduced-sensitivity caused false-blockage problem of the light curtain.

Ambient light interference compensation can include hardware, using filtered infrared light, modulating the emitter beams with an approximately 40 kilohertz signal. Alternatively, intelligent programming and/or possibly adjusting the beam numbers/spacing can be considered. Prevention of "false" product delivery sensing might be deterred by painting the inside of the vending chassis next to the delivery sensor. Paint with stronger texture seems to help prevent false senses.

In this embodiment, five sensors with 250 μs off time and 250 μs on time (500 μs total for each loop) generate 2000 iterations of the algorithm per second. It would take approximately 2500 μs to sequence through on/off of each of the five emitters. In comparison, if the algorithm turns the output line "on" for the time of 150 ms (150,000 μs), the output line will be held "on" for a minimum of 60 scans by the set of five emitters (150,000 divided by 500 = 300 divided by 5 = 60). Since the process loops or repeats, that output may remain closed longer than this period as the object passes through the beams.

The 150 milliseconds is the minimum duration in this embodiment. The output is basically retriggerable anytime the conditions shown in steps **212** or **232** exist.

The detection field consists of the array of infrared light beams from emitters **D**. The infrared detectors **U** are intended to detect when a product falls through the detection field and interrupts at least one of the light beams. If the main controller board **34** attempts to dispense an item, and the delivery sensor system does not detect it falling through its detection field, then the absence of a signal from the delivery sensor will show that the item failed to vend. When this happens, the master controller will make a second attempt to vend the item. Thus, the algorithm in co-pending Serial No. 10/023,058 kicks in.

The goal is to make the system resistant to a tolerable level of ambient light, e.g. illumination levels approximating direct sunlight. The light intensity value of direct sunlight is approximately 127,000 lux. The design goal for maximum tolerable ambient light is 60,000 lux.

This embodiment is designed to detect rectangular products as small as 1.912 by 3.029 by 0.028 inches in diameter and circular objects as small as 0.338 inches in diameter. Detection goals for the two shapes are in ideal conditions.

However, the system is not fool proof. As stated, there are "blind areas" or "dead zones." Certain regions within the grid may not detect products.

For example, with this methodology, each of the five emitters is turned on separately in a sequence with a space of time in between. As diagrammatically illustrated in **Figure 2A**, when emitter **D2** is on, although it is somewhat directional, it spreads in a manner that can be detected by each detector **U** if properly aligned (see beam spread indicated at angle **47**). However, during that time period, certain parts of the vend area **10** are not detected. In other words, a limited number of detectors **U**, being spaced apart, are

looking only for IR energy from a single emitter **D**. Because light travels in a straight line, at least areas indicated at reference numerals **41** and **42** are not covered by any detecting ability of detectors **U**. Detectors **U** are essentially blind to those areas (compare difference of angle **47** to angle **48**). Additionally, areas such as **43**, **44**, **45**, and **46** may not be covered because each hole has a "viewing angle "similar to the emitters.

Figure 2B illustrates the method when emitter **D5** (the middle emitter) is activated. Alignment of board **24** and **26** is such that each detector **U** sees IR energy from emitter **D5** when it is on. However, blind areas **41-46** still exist.

Similar blind areas exist when emitters **D3**, **D4**, and **D6** are on. However, some of the "blind spots" change for each emitter.

By further example, turning all emitters off for a period of time leaves the system intermittently "blind". Selection of the off time for all emitters was made with the following considerations. A complete "cycle" through the five emitters occurs once every 0.0005 seconds, or 2000 times per second. By rough calculation, an object that is, say, 3" long would take about 0.013 seconds to pass the sensors, or about 36 complete sensor scans. This estimate is derived by calculating the time gravity would accelerate such an object approximately six feet, which is most times the maximum drop distance for a vended product from a snack vending machine.

As can be appreciated, however, by cycling sequentially through emitters **D** in the short time duration indicated, the system attempts to cumulatively provide somewhat of an approximation of a "light curtain" between emitters **D** and detectors **U**. While not all emitters **D** are on at the same time, and there are blind spots for the system, balancing cost, complexity and other factors, this system provides what is considered a reasonable coverage of the vend area or reasonable confirmation of vend. The scanning of the

dispensing area by sequential operation of the emitters is believed to be a practical way to optimize light beam break detection with a minimum number of emitters and detectors, even if not all areas are covered.

D. Options and Alternatives

It will be appreciated that the invention can take a variety of forms and embodiments. The exemplary embodiment described above is made not by way of limitation to the invention, but for illustration of but one form the invention can take. Variations obvious to those skilled in the art are included within the invention, which is described solely by the claims appended hereto.

For example, the invention is not limited to five emitters and five detectors. However, it is preferred that the number be minimized and that there be spacing between emitters and between detectors.

The types of components and their operational states can vary. For example, in the exemplary embodiment, the emitters are considered active when off and the detectors are considered active when on. Timers and counters can vary depending on the reference used (e.g. the external crystal or on-board oscillator).

The specific algorithm for operation can vary. For example, emitter on and off times can be changed through programming.

The memory technology can include a feature of disabling the ability to extract the code from the memory device.

Environmental design considerations include temperature ranges, vibration, shock, ESD, EM resistance, and others such as are well known in the art. Goals are as follows: operating and storage temperature of -30 degree Fahrenheit to 185 degree Fahrenheit, operation under relative humidity of 20-90% non-condensing.

To address "dead zones" or "blind spots", options could include specialized code intended to exploit the large dimensions of objects such as cards having less than $1/16^{th}$ inch thickness, in the non-thickness direction. Alternatively, adaptive detection that would use more than just basic data in making a detection determination.

Appendix 1 – Emitter Board 20

Qty/ PCB	Device	Value	Unit	Tol	Volts/ Watts	Package	Manufac- turer	MFG Part Number	Description	Ref Designator
2	Capacitor, Aluminum, SMT, B Size	47	uF	0.2	6.3V		Panasonic	ECE-V0JA470WR	Capacitor, Aluminum	C1,C2
1	Resistor, 0603	4.7	ohm	0.05	1/16 W	603	Panasonic	ERJ-3GSYJ4R7V	Resistor, 0603	R13
5	Resistor, 0603	22	ohm	0.05	1/16 W	603	Panasonic	ERJ-3GSYJ220V	Resistor, 0603	R15,R22,R23,R24,R25
5	Infrared Diode	IR LED				1206	Kingbright	AP3216P3C	Infrared Diode	D1, D7, D8, D9, D10
1	Circuit Board	1" * 6"					Career	PCBFAWE MI1.1	Circuit Board, Double Sided 0.063", FR4	
1	Header	7-pin header					FCI	55101-xxx7	7 Contact, 0.1" RA header	J2
						Or	*Molex*	*22-28-8070*		
Unpopulated										
5	Infrared Diode, SMT, 1206 size	IR LED				TH	Lumex	OED-EL1206C140	Infrared Diode	D2,D3,D4, D5,D6
1	Wire Tie								3" 3/8" by .08" wide Wire Tie	

Appendix 2 -- Detector Board 26

Qty/ PCB	Device	Value	Unit	Tol	Volts/ Watts	Package	Manufacturer	MFG Part Number	Description	Ref Designator
6	Capacitor, Ceramic	0.1	uF	10 %	16V	603	Panasonic	ECJ-1VB1C104K	Capacitor, Ceramic	BP2,BP3,BP4,BP5,BP8, BPU1P2
2	Capacitor, Aluminum	47	uF	20 %	6.3V	CAP\ECE-VS_SIZE_C	Panasonic	ECE-V0JA470WR	Capacitor, Aluminum	C1, C7
1	Capacitor, Aluminum	33	uF	20 %	10V	CAP\ECE-VS_SIZE_C	Panasonic	ECE-V1AA330WR	Capacitor, Aluminum	C8
1	Capacitor, Aluminum	10	uF	20 %	35V	CAP\ECE-VS_SIZE_D	Panasonic	ECE-V1VA100WR	Capacitor, Aluminum	C6
1	LED, RED					1206	Lumex	SML-LX1206IW-TR	LED, RED	D2
1	Transistor, NPN, SOT-23	MMBT2222ALT1				SOT23	On Semi	MMBT2222ALT1	Transistor, NPN, SOT-23	Q6
2	Transistor, NPN, SOT-23	MMBTA06				SOT23	Diodes, Inc	MMBTA06	Transistor, NPN, SOT-23	Q8,Q9

10	Resistor, 0603	10K	ohm	0.05	1/16W	603	Panasonic	ERJ-3GSYJ103V	Resistor, 0603	R1,R10, R26,R28,R29,R30,R31,R32,R33, R35
8	Resistor, 1206	1000	ohm	0.05	1/8W	1206	Panasonic	ERJ-8GEYJ102	Resistor, 1206	R2, R3, R4, R5, R6, R9, R11, R27
5	Resistor, 0603	22	ohm	0.05	1/16W	603	Panasonic	ERJ-3GSYJ220V	Resistor, 0603	R15,R22,R23,R24,R25
2	Resistor, 0603	100	ohm	0.05	1/16W	603	Panasonic	ERJ-3GSYJ101V	Resistor, 0603	R7, R34
1	Resistor	0	ohm	5%	1/16W	0603	Panasonic	ERJ-3GSYJ000V	0 Ohm Resistor	R12
1	CPU	MSP430F1121				SMT	Ti	MSP430F1121PW	CPU	U1
5	Optical Detector					TH	Lumex	OED-MRM791-2F	Optical Detector	U2,U3, U4,U5, U8
1	LM1086IS					TO263\3 smt	National	LM1086IS-5.0	LM1086IS	U6
1	LM1086IS					TO263\3 smt	National	LM1086IS-3.3	LM1086IS	U7
1	LM809					SOT23	National	LM809M3-2.93	LM809 Reset Device	U9
1	MOV	Series 7,			68	TH	Panasonic	ERZ-V07D680	MOV Device	Z1

	Device	Type D			WVDC					
1	Crystal	8.00 MHz				SMT	Panasonic	EFO-S8004E5	Crystal	Y1
1	Circuit Board	1" * 6"					Career	PCBFAWDET1.1	Circuit Board, Double Sided FR4	
1	Header	7-pin header					FCI	55101-xxx7	7 Contact, 0.1" RA header	J2
						Or	*Molex*	*22-28-8070*		
1	Cable	98"					General Cable	C4064-12-10	5 Conductor 22 AWG, CPU Cable	
1	Housing						Molex	09-50-8150	.156 Pitch 15 Pin CPU Cable Housing	
						Or	*Amp*	*1-640251-5*		
4	Contacts						Molex	08-50-0134	4 Contacts for the CPU Cable	
						Or	*Amp*	*350980-1*		
2	Plugs						Molex	15-04-0297	Polarity Plugs for CPU Cable Header	
						Or	*Amp*	*640254-1*		
1	Wire Tie								3" 3/8" by .08" wide Wire Tie	
Unpopulated:										
2	Capacitor, Ceramic	22pF	pF	0.05	50V	603	Panasonic	ECJ-1VC1H220J	Capacitor, Ceramic	C3,C4
1	Capacitor, Aluminum	47	uF	20%	6.3V	CAP\ECE-VS_SIZE	Panasonic	ECE-V0JA470WR	Capacitor, Aluminum	C2

						_C				
1	Capacitor, Aluminum	10UF	uF	20 %	16V	CAP\ECE-VS_SIZE_B	Panasonic	ECEV1CA100SR	Capacitor, Aluminum	C5
1	Diode	DL4148				MLL34	Diodes Inc.	DL4148	Diode	D1
1	Transistor, PNP, SOT-23	MMBT2907				SOT23	On Semi	MMBT2907A	Transistor, PNP, SOT-23	Q5
1	Resistor, 0603	4.7	ohm	0.05	1/16W	603	Panasonic	ERJ-3GSYJ4R7V	Resistor, 0603	R13
1	Resistor	0	ohm	5 %	1/16W	0603	Panasonic	ERJ-3GSYJ000V	0 Ohm Resistor	R8
1	Resistor, 1206	1000	ohm	0.05	1/8W	1206	Panasonic	ERJ-8GEYJ102	Resistor, 1206	R14
1	Wire Tie								3" 3/8" by .08" wide Wire Tie	
3	2 pin Header								2-pin Header (Jumper)	JP1, JP2, JP3
1	2 x 7 pin Header								Debug / Programming Header	J3

Appendix 3 – Interconnect Cable 28

Qty/ PCB	Device	Value	Unit	Tol	Volts/ Watts	Package	Manufacturer	MFG Part Number	Description	Ref Designator
2	Housing						Molex	22-01-2071	Housing, 7 pin	
14	Contacts						Molex	08-50-0113	Contacts	
1	Cable						General Cable		58", 22 AWG, 7 Cond. Cable	